SOME ASPECTS OF INDUSTRIAL CHEMISTRY

BY

L. H. BAEKELAND, Sc.D.

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THE CHANDLER LECTURE

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WHILE I appreciate deeply the distinction of speaking before you on the occasion of the Fiftieth Anniversary of the Columbia School of Mines, I realize, at the same time, that nobody here present could do better justice to the subject which has been chosen for this lecture than the beloved master in whose honor the Charles Frederick Chandler Lectureship has been created.

Dr. Chandler, in his long and eminently useful career as a professor and as a public servant, has assisted at the very beginning of some of the most interesting chapters of applied chemistry, here and abroad.

Some of his pupils have become leaders in chemical industry; others have found in his teachings the very conception of new chemical processes which made their names known throughout the whole world.

Industrial chemistry has been defined as "the chemistry of dollars and cents."

Is industrial chemistry a mere money-making proposition?

This rather cynical definition, in its narrower interpretation, seems to ignore entirely the far-reaching economic and civilizing influences which have been brought to life through the applications of science; it fails to do justice to the fact that the whole fabric of modern civilization becomes each day more and ever more interwoven with the endless ramifications of applied chemistry.

The earlier effects of this influence do not date back much

beyond one hundred and odd years. They became distinctly evident during the first French Republic, increased under Napoleon, gradually spread to neighboring countries, and then reaching out farther, their influence is now obvious throughout the whole world.

Beginnings of chemical industries

The French Republic and Napoleon

France, during the revolution, scattered to the winds old traditions and conventionalities, in culture as well as in politics. Until then, she had mainly impressed the world by the barbaric, wasteful splendor of her opulent kings, at whose courts the devotees of science received scant attention in comparison to the more ornamental artists and belles-lettrists, who were petted and rewarded alongside of the all-important men of the sword.

The kings of France neglected science in favor of arts and literature

In fact, as far as the culture of science was concerned, the Netherlands, Germany and Italy, and more particularly, England, were head and shoulders above the France of "le Roi Soleil."

The struggles of the new régime put France in the awkward position of the legendary beaver which "had to climb a tree."

If for no other reason, she needed scientists to help her in her wars against the rulers of other European nations. She needed them just as much for repairing her crippled finances and her badly disturbed industries which were dependent upon natural products imported until then, but of which the supply had suddenly been cut off by the so-called Continental Blockade. Money-prizes and other inducements had been offered for stimulating the development of chemical processes, and—what is more significant—patent laws were promulgated so as to foster invention.

Creation of French patent system

Nicolas Leblanc's method for the manufacture of soda

to replace the imported alkalis, Berthollet's method for bleaching with chlorine, the beet-sugar industry to replace cane sugar imported from the colonies, and several other processes, were proposed.

All these chemical processes found themselves soon lifted from the hands of the secretive alchemist or the timid pharmacist to the rank of real manufacturing methods: Industrial chemistry had begun its lusty career.

First successes stimulated new endeavors and small wonder is it that France, with these favorable conditions at hand, for a while at least, entered into the most glorious period of that part of her history which relates to the development of chemistry, and the arts dependent thereon.

Backward position of Germany

It is difficult to imagine that, at that time, Germany, which now occupies such an enviable position in chemistry, was so far behind that even in 1822, when Liebig wanted to study chemistry at the best schools, he had to leave his own country, and turn to Gay-Lussac, Thénard and Dulong in Paris.

Development of British chemical industry

But the British were not slow to avail themselves of the new opportunities in chemical manufacturing so clearly indicated by the first successes of the French. Their linen bleacheries in Scotland and England soon used an improved method for bleaching with chloride of lime, developed by Tennant, which brought along the manufacture of other chemicals relating thereto, like sulphuric acid and soda.

The chemical reactions involved in all these processes are relatively simple, and after they were once well understood, it required mainly resourceful engineering and good commercial abilities to build up successfully the industries based thereon.

From this epoch on dates the beginning of the development of that important industry of heavy chemicals in which the British led the world for almost a century.

In the same way, England had become the leader in another important branch of chemical industry—the manufacture of coal-gas.

Liebig's influence in Germany

The Germans were soon to make up for lost time. Those same German universities, which when Liebig was a young man were so poorly equipped for the study of chemistry, were now enthusiastically at work on research along the newer developments of the physical sciences, and, before long, the former pupils of France, in their turn, became teachers of the world.

Liebig had inaugurated for the chemical students working under him his system of research laboratories; however modest these laboratories may have been at that time, they carried bodily the study of chemistry from pedagogic boresomeness into a captivating cross-examination of nature.

And it seemed as if nature had been waiting impatiently to impart some of her secrets to the children of men, who for so many generations had tried to settle Truth and Knowledge by words and oratory and by brilliant displays of metaphysical controversies.

Indeed, at that time, a few kitchen tables, some clumsy glass-ware, a charcoal furnace or two, some pots and pans, and a modest balance were all that was needed to make nature give her answers.

Development of organic chemistry in Germany

These modest paraphernalia, eloquent by their very simplicity, brought forth rapidly succeeding discoveries. One of them was truly sensational: Liebig and Wöhler succeeded in accomplishing the direct synthesis of urea; thinking men began to realize the far-reaching import of this revolutionary discovery whereby a purely organic substance had been created in the laboratory by starting exclusively from inorganic materials. This result upset all respected doc-

trines that organic substances are of a special enigmatic constitution, altogether different from inorganic or mineral compounds, and that they only could be built up by the agency of the so-called "vital force"—whatever that might mean.

Research in organic chemistry became more and more fascinating; all available organic substances were being investigated one after another by restless experimentalists.

In Germany

The influence of Kékulé's theory

Coal-tar, heretofore a troublesome by-product of gas manufacture, notwithstanding its uninviting, ill-smelling, black sticky appearance, did not escape the general inquisitive tendency; some of its constituents, like benzol or others, were isolated and studied.

Under the brilliant leadership of Kékulé, a successful attempt was made to correlate the rapidly increasing new experimental observations in organic chemistry into a new theory which would try to explain all the numerous facts; a theory which became the sign-post to the roads of further achievements.

Discovery of artificial dyes

The discovery of quickly succeeding processes for making from coal-tar derivatives numerous artificial dyes, rivaling, if not surpassing, the most brilliant colors of nature, made the group of bold investigators still bolder. Research in organic chemistry began to find rapid rewards; entirely new and successful industries based on purely scientific data were springing up in England and France, as well as in Germany.

Stimulating influences of the dye industry on organic chemistry

Some wide-awake leaders of these new enterprises, more particularly in Germany, soon learned that they were never hampered by too much knowledge, but that, on the contrary, they were almost continuously handicapped in their impatient onward march by insufficient know-

ledge, or by misleading conceptions, if not by incorrect published facts.

This is precisely where the study of organic chemistry received its greatest stimulating influence and soon put Germany, in this branch of science, ahead of all other nations.

Money and effort had to be spent freely for further research. The best scholars in chemistry were called into action. Some men, who were preparing themselves to become professors, were induced to take a leading part as directors in one or another of the new chemical enterprises. Others, who refused to forsake their teachers' career, were retained as advisers or guides, and, in several instances, the honor of being the discoverers of new processes, or a new dye, was made more substantial by financial rewards. The modest German university professor, who heretofore had lived within a rather narrow academic sphere, went through a process of evolution, where the rapidly growing chemical industry made him realize his latent powers and greater importance, and broadened his influence way beyond the confines of his lecture-room. Even if he were altruistic enough to remain indifferent to fame or money, he felt stimulated by the very thought that he was helping, in a direct manner, to build up the nation and the world through the immediate application of the principles of science.

Industrial research laboratories

In the beginning, science did all the giving and chemical industry got most of the rewards; but soon the rôles began to change to the point where frequently they became entirely inverted. The universities did not furnish knowledge fast enough to keep pace with the requirements of the rapidly developing new industries. Modern research laboratories were organized by some large chemical factories on a scale never conceived before, with a lavishness which made the best equipped

university laboratory appear like a timid attempt. Germany, so long behind France and England, had become the recognized leader in organic manufacturing processes, and developed a new industrial chemistry based more on the thorough knowledge of organic chemistry than on engineering skill.

Early German chemical industry more important in variety than in size

In this relation, it is worth while to point out that the early organic industrial chemistry, through which Germany was soon to become so important, at first counted its output not in tons, but in pounds—not in size nor in quantity, but in variety and quality.

Now let us see how Germany won her spurs in chemical engineering as well:

Development of chemical engineering in Germany

At the beginning, the manufacturing problems in organic chemistry involved few, if any, serious engineering difficulties, but required, most of all, a sound theoretical knowledge of the subject; this put a premium on the scientist, and could afford, for awhile at least, to ignore the engineer. But when growing developments began to claim the help of good engineers, there was no difficulty whatsoever in supplying them, nor in making them coöperate with the scientists. In fact, since then, Germany has solved, just as successfully, some of the most extraordinary chemical engineering problems ever undertaken, although the development of such processes was entered upon at first from the purely scientific side.

In almost every case, it was only after the underlying scientific facts had been well established, that any attempt was made to develop them commercially.

Methods of healthy development of scientific processes

Healthy commercial development of new scientific processes does not build its hope of success upon the coöperation of that class of "promoters" which are always eager to find

any available pretext for making "quick money," and whose scientific ignorance contributes conveniently to their comfort by not interfering too much with their self-assurance and their voluble assertions. The history of most of the successful recent chemical processes abounds in examples where, even after the underlying principles were well established, long and costly preparatory team-work had to be undertaken; where foremost scientists, as well as engineers of great ability, had to combine their knowledge, their skill, their perseverance, with the support of large chemical companies, who, in their turn, could rely on the financial backing of strong banking concerns, well advised by tried expert specialists.

Scientific banking

History does not record how many processes thus submitted to careful study were rejected because, on close examination, they were found to possess some hopeless shortcomings. In this way, numerous fruitless efforts and financial losses were averted, where less carefully accumulated knowledge might have induced less scrupulous promoters to secure money for plausible but ill-advised enterprises.

Synthesis of indigo

In the history of the manufacture of artificial dyes, no chapter gives a more striking instance of long, assiduous and expensive preliminary work of the highest order than the development of the industrial synthesis of indigo. Here was a substance of enormous consumption which, until then, had been obtained from the tropics as a natural product of agriculture. Professor von Baeyer and his pupils, by long and marvelously clever laboratory work, succeeded by and by in unraveling the chemical constitution of this indigo dye, and finally indicated some possible methods of synthesis. Notwithstanding all this, it took the Badische Ani-

line & Soda Fabrik about twenty years of patient research work, carried out by a group of eminent chemists and engineers, before a satisfactory method was devised by which the artificial product could compete in price and in quality with natural indigo.

Stimulating influences of a good patent system

Germany, with her well administered and easily enforcible patent laws, has added, through this very agency, a most vital inducement for pioneer work in chemical industries. Who otherwise would dare to take the risk of all the expenses connected with this class of creative work? Moreover, who would be induced to publish the result of his discoveries far and wide throughout the whole world in that steadily flowing stream of patent literature, which, much sooner than any text-books or periodicals, enables one worker to be benefited and to be inspired by the publication of the latest work of others?

International scope of chemical research

The development of some problems of industrial chemistry has enlisted the brilliant collaboration of men of so many different nationalities that the final success could not, with any measure of justice, be ascribed exclusively to one single race or nation; this is best illustrated by the invention of the different methods for the fixation of nitrogen from the air.

An Epos of Applied Science

This extraordinary achievement, although scarcely a few years old, seems already an ordinary link in the chain of common, current events of our busy life; and yet, the facts connected with this recent conquest reveal a modern tale of great deeds of the race—an Epos of Applied Science.

Its story began the day when chemistry taught us how indispensable are the nitrogeneous substances for the growth of all living beings.

Generally speaking, the most expensive food-stuffs are

precisely those which contain most nitrogen; for the simple reason that there is, and always has been, at sometime or another, a shortage of nitrogeneous foods in the world. Agriculture furnishes us these proteid- or nitrogen-containing bodies, whether we eat them directly as vegetable products, or indirectly as animals which have assimilated the proteids from plants. It so happens, however, that by our ill-balanced methods of agriculture, we take nitrogen from the soil much faster than it is supplied to the soil through natural agencies. We have tried to remedy this discrepancy by enriching the soil with manure or other fertilizers, but this has been found totally insufficient, especially with our methods of intensive culture—our fields want more nitrogen. So agriculture has been looking anxiously around to find new sources of nitrogen fertilizer. For a short time, an excellent supply was found in the guano deposits of Peru; but this material was used up so eagerly that the supply lasted only a very few years. In the meantime, the ammonium salts recovered from the by-products of the gas-works have come into steady use as nitrogen fertilizer. But, here again, the supply is entirely insufficient, and during the later period our main reliance has been placed on the natural beds of sodium nitrate, which are found in the desert regions of Chile. This has been, of late, our principal source of nitrogen for agriculture, as well as for the many industries which require saltpeter or nitric acid.

Deficiency of nitrogen fertilizers in agriculture

Guano

Chile saltpeter and its approaching exhaustion

In 1898, Sir William Crookes, in his memorable presidential address before the British Association for the Advancement of Science, called our attention to the threatening fact that, at the increasing rate of consumption, the nitrate beds of Chile would be exhausted before the middle of this century. Here was a warning—an alarm call—

raised to the human race by one of the deepest scientific thinkers of our generation. It meant no more nor less than that before long our race would be confronted with nitrogen starvation. In a given country, all other conditions being equal, the abundance or the lack of nitrogen available for nutrition is a paramount factor in the degree of general welfare, or of physical decadence. The less nitrogen there is available as food-stuffs, the nearer the population is to starvation. The great famines in such nitrogen-deficient countries as India and China and Russia are sad examples of nitrogen starvation.

Nitrogen starvation

And yet, nitrogen, as such, is so abundant in nature that it constitutes four-fifths of the air we breathe. Every square mile of our atmosphere contains nitrogen enough to satisfy our total present consumption for over half a century. However, this nitrogen is unavailable as long as we do not find means to make it enter into some suitable chemical combination. Moreover, nitrogen was generally considered inactive and inert, because it does not enter readily in chemical combination.

William Crookes' disquieting message of rapidly approaching nitrogen starvation did not cause much worry to politicians—they seldom look so far ahead into the future. But, to the men of science, it rang like a reproach to the human race. Here, then, we were in possession of an inexhaustible store of nitrogen in the air, and yet, unless we found some practical means for tying some of it into a suitable chemical combination, we would soon be in a position similar to that of a shipwrecked sailor, drifting around on an immense ocean of brine, and yet slowly dying for lack of drinking water.

The Priestley-Cavendish experiment

As a guiding beacon, there was, however, that simple experiment, carried out in a little glass tube, as far back as 1785, by both Cavendish and

Priestley, which showed that if electric sparks were passed through air, the oxygen thereof was able to burn some of the nitrogen and to engender nitrous vapors.

Bradley and Lovejoy

This seemingly unimportant laboratory curiosity, so long dormant in the text-books, was made a starting point by Charles S. Bradley and D. R. Lovejoy, in Niagara Falls, for creating the first industrial apparatus for converting the nitrogen of the air into nitric acid by means of the electric arc.

As early as 1902, they published their results as well as the details of their apparatus. Although they operated only one full-sized unit, they demonstrated conclusively that nitric acid could thus be produced from the air in unlimited quantities. We shall examine later the reasons why this pioneer enterprise proved a commercial insuccess; but to these two American inventors belongs, undoubtedly, the credit of having furnished the first answer to the distress call of Sir William Crookes.

Birkeland and Eyde

In the meantime, many other investigators were at work at the same problem, and soon from Norway's abundant waterfalls came the news that Birkeland and Eyde had solved successfully, and on a commercial scale, the same problem by a differently constructed apparatus. The Germans, too, were working on the same subject, and we heard that Schoenherr, also Pauling, had evolved still other methods, all, however, based on the Cavendish-Priestley principle of oxidation of nitrogen. In Norway alone, the artificial saltpeter factories use now, day and night, over 200,000 electrical horse-power, which will soon be doubled; while a further addition is contemplated which will bring the volume of electric current consumed to about 500,000 horse-power. The capital invested at present in these works amounts to $27,000,000.

Pauling and Schoenherr

Frank and Caro, in Germany, succeeded in creating another profitable industrial process whereby nitrogen could be fixed by carbide of calcium, which converts it into calcium cyanamide, an excellent fertilizer by itself. By the action of steam on cyanamide, ammonia is produced, or it can be made the starting point of the manufacture of cyanides, so profusely used for the treatment of gold and silver ores.

Frank and Caro's cyanamide

Although the synthetic nitrates have found a field of their own, their utilization for fertilizers is smaller than that of the cyanamide; and the latter industry represents, to-day, an investment of about $30,000,000, with three factories in Germany, two in Norway, two in Sweden, one in France, one in Switzerland, two in Italy, one in Austria, one in Japan, one in Canada, but not any in the United States. The total output of cyanamide is valued at $15,000,000 yearly and employs 200,000 horse-power, and preparations are made at almost every existing plant for further extensions. An English company is contemplating the application of 1,000,000 horse-power to the production of cyanamide and its derivatives, 600,000 of which have been secured in Norway and 400,000 in Iceland.

Nitride processes

But still other processes are being developed, based on the fact that certain metals or metalloids can absorb nitrogen, and can thus be converted into nitrides; the latter can either be used directly as fertilizers or they can be made to produce ammonia under suitable treatment.

Serpek process

The most important of these nitride processes seems to be that of Serpek, who, in his experimental factory at Niedermorschweiler, succeeded in obtaining aluminum nitride in almost theoretical quantities, with the use of an amount of electrical energy eight times less than that needed for the Birkeland-Eyde process and one-half less than for the cyanamide

process, the results being calculated for equal weights of "fixed" nitrogen.

A French company has taken up the commercial application of this process which can furnish, besides ammonia, pure alumina for the manufacture of aluminum metal.

Haber's process

An exceptionally ingenious process for the direct synthesis of ammonia, by the direct union of hydrogen with nitrogen, has been developed by Haber in conjunction with the chemists and engineers of the Badische Aniline & Soda Fabrik.

The process has the advantage that it is not, like the other nitrogen-fixation processes, paramountly dependent upon cheap power; for this reason, if for no other, it seems to be destined to a more ready application. The fact that the group of the three German chemical companies which control the process have sold out their former holdings in the Norwegian enterprises to a Norwegian-French group, and are now devoting their energies to the commercial installation of the Haber process, has quite some significance as to expectations for the future.

The future of nitrogen-fixation processes

The question naturally arises: Will there be an over-production and will these different rival processes not kill each other in slaughtering prices beyond remunerative production?

As to over-production, we should bear in mind that nitrogen fertilizers are already used at the rate of about $200,000,000 worth a year, and that any decrease in price, and, more particularly, better education in farming, will probably lead to an enormously increased consumption. It is worth mentioning here that, in 1825, the first ship-load of Chile saltpeter which was sent to Europe could find no buyer, and was finally thrown into the sea as useless material.

Then again, processes for nitric acid and processes for ammonia, instead of interfering, are supplementary to

each other, because the world needs ammonia and ammonium salts, as well as nitric acid or nitrates.

It should be pointed out also, that, ultimately, the production of ammonium nitrate may prove the most desirable method so as to minimize freight; for this salt contains much more nitrogen to the ton than is the case with the more bulky calcium-salt under which form synthetic nitrates are now put into the market.

Why did Bradley and Lovejoy not succeed?

Before leaving this subject, let us examine why Bradley and Lovejoy's efforts came to a standstill where others succeeded.

First of all, the cost of power at Niagara Falls is three to five times higher than in Norway, and although at the time this was not strictly prohibitive for the manufacture of nitric acid, it was entirely beyond hope for the production of fertilizers. The relatively high cost of power in our country is the reason why the cyanamide enterprise had to locate on the Canadian side of Niagara Falls, and why, up till now, outside of an experimental plant in the South (a 4000 horse-power installation in North Carolina, using the Pauling process), the whole United States has not a single synthetic nitrogen fertilizer works.

The yields of the Bradley-Lovejoy apparatus were rather good. They succeeded in converting as much as $2\frac{1}{2}\%$ of the air, which is somewhat better than their successors are able to accomplish.

But their units, 12 kilowatts, were very much smaller than the 1000 to 3000 kilowatts now used in Norway; they were also more delicate to handle, all of which made installation and operation considerably more expensive.

However, this was the natural phase through which any pioneer industrial development has to go, and it is more than probable that in the natural order of events, these imperfections would have been eliminated.

But the killing stroke came when financial support was suddenly withdrawn.

Necessity of scientific team-work and good financial backing

In the successful solution of similar industrial problems, the originators in Europe were not only backed by scientifically well-advised bankers, but they were helped to the rapid solution of all the side problems by a group of specially selected scientific collaborators, as well as by all the resourcefulness of well-established chemical enterprises.

That such conditions are possible in the United States has been demonstrated by the splendid team-work which led to the development of the modern Tungsten lamp in the research laboratories of the General Electric Company, and to the development of the Tesla polyphase motor by the group of engineers of the Westinghouse Company.

True, there are endless subjects of research and development which can be brought to success by the efforts of single independent inventors, but there are some problems of applied science which are so vast, so much surrounded with ramifying difficulties, that no one man, nor two men, however exceptional, can either furnish the brains or the money necessary for leading to success within a reasonable time. For such special problems, the rapid coöperation of numerous experts and the financial resources of large establishments are indispensable.

Dollars and cents a criterion of efficiency

All these examples of the struggle for efficiency and improvement demonstrate why, in industrial chemistry, the question of *dollars and cents* has to be taken very much into consideration.

From this standpoint at least, the "Dollars and cents" argument can be interpreted as a symptom of industrial efficiency, and thus, the definition sounds no longer as a reproach. With some allowable degree of accuracy, it for-

mulates one of the economic aspects of any acceptable industrial chemical process.

Indeed, barring special conditions, as, for instance, incompetent or reckless management, unfair competition, monopolies, or other artificial privileges, the money success of a chemical process is the cash plebiscite of approval of the consumers. It is bound, after a time at least, to weed out the inefficient methods.

Influence of secondary factors in chemical processes

Some chemists, who have little or no experience with industrial enterprises, are too much over-inclined to judge a chemical process exclusively from the standpoint of the chemical reactions involved therein, without sufficient regard to engineering difficulties, financial requirements, labor problems, market and trade conditions, rapid development of the art involving frequent disturbing improvements in methods and expensive changes in equipment, advantages or disadvantages of the location of the plant, and other conditions so numerous and variable that many of them can hardly be foreseen even by men of experience.

And yet, these seemingly secondary considerations most of the time become the deciding factor of success or failure of an otherwise well-conceived chemical process.

Influence of freight

The cost of transportation alone will frequently decide whether a certain chemical process is economically possible or not. For instance, the big Washoe Smelter, in Montana, wastes enough sulphurdioxide-gas to make daily 1800 tons of sulphuric acid, but that smelter is too far distant from any possible market for such a quantity of otherwise valuable material.

Natural deposits of soda

Another example of the kind is found in the natural deposits of soda, or soda lakes, in California. One of these soda lakes contains from thirty to forty-two million tons of soda. Here is a natural source of supply which would be ample to satisfy the

world's demand for many years to come. Similar deposits exist in other parts of the world, but the cost of transportation to a sufficiently large and profitable market is so exorbitant that, in the meantime, it is cheaper to erect at more convenient points expensive chemical works in which soda is made chemically and from where the market can be supplied more profitably.

In addition, we can cite the artificial nitrate processes in Norway, which, notwithstanding their low efficiency and expensive installation, can furnish nitrate in competition with the natural nitrate beds of Chile, because the latter are hampered by the cost of extraction from the soil where fuel for crystallization is expensive, in addition to the considerable cost of freight.

Leblanc soda

But there is no better example, illustrating the far-reaching effect of seemingly secondary conditions upon the success of a chemical process, than the history of the Leblanc soda process.

This famous process was the forerunner of chemical industry: for almost a century, it dominated the enormous group of industries of heavy chemicals, so expressively called by the French: "La Grande Industrie Chimique," and now we are witnesses of the lingering death agonies of this chemical colossus. Through the Leblanc process, large fortunes have been made and lost; but even after its death, it will leave a treasure of information to science and chemical engineering, the value of which can hardly be overestimated.

Here, then, is a very well worked-out process, admirably studied in all its details, which, in its heroic struggle for existence, has drawn upon every conceivable resource of ingenuity furnished by the most learned chemists and the most skilful engineers, who succeeded in bringing it to an extraordinary degree of perfection, and which, nevertheless, has to succumb before inexorable, although seemingly secondary, conditions.

Strange to say, its competitor, the Solvay process, entered into the arena after a succession of failures. When Solvay, as a young man, took up this process, he was, himself, totally ignorant of the fact that no less than about a dozen able chemists had invented and reinvented the very reaction on which he had pinned his faith; that, furthermore, some had tried it on a commercial scale, and had, in every instance, encountered failure. At that time, all this must, undoubtedly, have been to young Solvay a revelation sufficient to dishearten almost anybody. But he had one predominant thought to which he clung as a last hope of success, and which would probably have escaped most chemists; he reasoned that, in this process, he starts from two watery solutions, which, when brought together, precipitate a dry product, bicarbonate of soda; in the Leblanc process, the raw materials must be melted together, with the use of expensive fuel, after which the mass is dissolved in water, losing all these valuable heat units, while more heat has again to be applied to evaporate to dryness.

Solvay process

After all, most of the weakness of the Leblanc process resides in the greater consumption of fuel. But the cost of fuel, here again, is determined by freight rates. This is so true that we find that the last few Leblanc works which manage to keep alive are exactly those which are situated near unusually favorable shipping points, where they can obtain cheap fuel, as well as cheap raw materials, and whence they can most advantageously reach certain profitable markets.

Greater consumption of fuel in Leblanc process

But another tremendous handicap of the Leblanc process is that it gives as one of its by-products, hydrochloric acid. Profitable use for this acid, as such, can be found only to a limited extent. It is true that hydrochloric acid could be used in

Hydrochloric acid a troublesome by-product

much larger quantities for many purposes where sulphuric acid is used now, but it has, against sulphuric acid, a great freight disadvantage. In its commercially available condition, it is an aqueous solution, containing only about one-third of real acid, so that the transportation of one ton of acid practically involves the extra cost of freight of about two tons of water. Furthermore, the transportation of hydrochloric acid in anything but glass carboys involves very difficult problems in itself, so that the market for hydrochloric acid remains always within a relatively small zone from its point of production. However, for a while at least, an outlet for this hydrochloric acid was found by converting it into a dry material which can easily be transported; namely, chloride of lime or bleaching-powder.

Chloride of lime

The amount of bleaching-powder consumed in the world practically dictated the limited extent to which the Leblanc process could be profitably worked in competition with the Solvay process. But even this outlet has been blocked during these later years by the advent of the electrolytic alkali processes, which have sprung up successfully in several countries, and which give as a cheap by-product, chlorine, which is directly converted into chloride of lime.

Electrolytic processes a new competitor

To-day, any process which involves the production of large quantities of hydrochloric acid, beyond what the market can absorb as such, or as derivatives thereof, becomes a positive detriment, and foretells failure of the process. Even if we could afford to lose all the acid, the disposal of large quantities thereof conflicts immediately with laws and ordinances relative to the pollution of the atmosphere or streams, or the rights of neighbors, and occasions expensive damage suits.

Market for chlorine products

Whatever is said about hydrochloric acid, applies to some extent to chlorine, produced in

the electrolytic manufacture of caustic soda. Here again, the development of the latter industry is limited, primarily, by the amount of chlorine which the market, as such, or as chlorinated products, can absorb.

At any rate, chlorine can be produced so much cheaper by electrolytic caustic alkali processes than formerly, and in the meantime the market price of chloride of lime has already been cut about in half.

In as far as the rather young electrolytic alkali industry has taken a considerable development in the United States, let us examine it somewhat nearer:

World's production of chloride of lime—half million tons

At present, the world's production of chloride of lime approximates about half a million tons.

We used to import all our chloride of lime from Europe, until about fifteen years ago, when the first successful electrolytic alkali works were started at Niagara Falls. That ingenious mercury cell of Hamilton Y. Castner—a pupil of Professor Chandler and one of the illustrious sons of the Columbia School of Mines—was first used, and his process still furnishes a large part of all the electrolytic caustic soda and chlorine manufactured here and abroad.

Castner

30,000 horse-power used in the United States for electrolytic alkali production

At present, about 30,000 electrical horse-power are employed uninterruptedly for the different processes used in the United States, and our home production has increased to the point where, instead of importing chloride of lime, we shall soon be compelled to export our surplus production.

Nearness of over-production

It looks now as if, for the moment at least, any sudden considerable increase in the production of chloride of lime would lead to over-production until new channels of consumption of chloride of lime or other chlorine products can be found.

However, new uses for chlorine are being found every day. The very fact that commercial hydrochloric acid of exceptional purity is now being manufactured in Niagara Falls by starting from chlorine, indicates clearly that conditions are being reversed; no longer than a few years ago, when chlorine was manufactured exclusively by means of hydrochloric acid, this would have sounded like a paradox.

New uses for chlorine

Hydrochloric acid from chlorine

Organic chlorine products

The consumption of chlorine for the preparation of organic chlorination products utilized in the dye-stuff industry, is also increasing continually, and its use for the manufacture of tetrachloride of carbon and so-called acetylen chlorination products, has reached quite some importance.

Ethylen-chloride

There is probably a much overlooked but wider opening for chlorinated solvents in the fact that ethylen-gas can be prepared now at considerably lower cost than acetylen, and that ethylenchloride, or the old known "Dutch Liquid," is an unusually good solvent. It has, furthermore, the great advantage that its specific gravity is not too high, and its boiling point, too, is about the right temperature. It ought to be possible to make it at such a low price that it would find endless applications where the use of other chlorination solvents has thus far been impossible.

Chlorine in metallurgy

The chlorination of ores for certain metallurgical processes may eventually open a still larger field of consumption for chlorine.

Increasing use of liquified chlorine

In the meantime, liquified chlorine gas, obtained by great compression, or by intense refrigeration, has become an important article of commerce, which can be transported in strong steel cylinders. Its main utiiization resides in the manufacture of tin chloride by the Goldschmidt process for

reclaiming tin-scrap. It is finding, also, increased applications as a bleaching agent and for the purification of drinking water, as well as for the manufacture of various chlorination products.

Goldschmidt process for detinning

Its great handicap for rapid introduction is again the question of freight, where heavy and expensive containers become indispensable.

In most cases, the transportation problem of chlorine is solved more economically by handling it as chloride of lime, which, after all, represents chlorine or oxygen in solid form, easily transportable.

Freight problem in relation to chlorine

It would seem as if the freight difficulty could easily be eliminated by producing the chlorine right at the spot of consumption. But this is not always so simple as it may appear. To begin with, the cost of an efficient plant for any electrolytic operation is always unusually high as compared to other chemical equipments. Then, also, small electrolytic alkali plants are not profitable to operate. Furthermore, the conditions for producing cheap chlorine depend on many different factors, which all have to coördinate advantageously; for instance, cheap power, cheap fuel, and cheap raw materials are essential, while, at the same time, a profitable outlet must be found for the caustic soda.

Lately, there has been a considerable reduction of the market price of caustic soda; all this may have for effect that the less efficient electrolytic processes will gradually be eliminated; although this may not necessarily be the case for smaller plants which do not compete in the open market, but consume their own output for some special purpose.

Advantages and disadvantages of different types of electrolytic alkali cells

Several distinct types of electrolytic cells are now in successful use, but experience seems to demonstrate that the so-called diaphragm cells are cheapest to construct and to operate, pro-

vided, however, no exception be taken to the fact that the caustic soda obtained from diaphragm cells always contains some sodium chloride, usually varying from 2 to 3%, which it is not practical to eliminate, but which, for almost all purposes, does not interfere in the least with its commercial use.

Mercury cells give a much purer caustic soda, and this may, in some cases, compensate for their more expensive equipment and operation. Moreover, there are some purposes where the initial caustic solution of rather high concentration, produced directly in these cells, can be used as it is without further treatment, thus obviating further concentration and cost of fuel.

The expenses for evaporation and elimination of salt from the raw caustic solutions increase to an exaggerated extent with some types of diaphragm cells, which produce only very weak caustic liquors. This is also the case with the so-called "gravity cell," sometimes called the "bell type," or "Aussig type," of cell. But these gravity cells have the merit of dispensing with the delicate and expensive problem of diaphragms. On the other hand, their units are very small, and, on this account, they necessitate a rather complicated installation, occupying an unusually large floor space and expensive buildings.

The general tendency is now toward cells which can be used in very large units, which can be housed economically, and of which the general cost of maintenance and renewal is small; some of the modern types of diaphragm cells are now successfully operating with 3000 to 5000 amperes per cell.

As to the possible future improvements in electrolytic alkali cells, we should mention that in some types the current efficiencies have practically reached their maximum, and average ampere efficiencies as high as 95 to 97% have been obtained in continuous practice. The main diffi-

culty is to reinforce these favorable results by the use of lower voltage, without making the units unnecessarily bulky, or expensive in construction, or in maintenance, all factors which soon outweigh any intended saving of electric current.

Here, more than in any other branch of chemical engineering, it is easy enough to determine how "good" a cell is on a limited trial, but it takes expensive, long continuous use on a full commercial scale, running uninterruptedly day and night for years, to find out how "bad" it is for real commercial practice.

Cheap power not the only factor

In relation to the electrolytic alkali industry, a great mistake is frequently committed by considering the question of power as paramount; true enough, cheap power is very important, almost essential, but certainly it is not everything. There have been cases where it was found much cheaper in the end to pay almost double for electric current in a certain locality, than in another site not far distant from the first, for the simple reason that the cheaper power supply was hampered by frequent interruptions and expensive disturbances, which more than offset any possible saving in cost of power.

In further corroboration, it is well known that some of the most successful electrolytic soda manufacturers have found it to their advantage to sacrifice power by running their cells at decidedly higher voltage than is strictly necessary—which simply means consuming more power—and this in order to be able to use higher current densities, thereby increasing considerably the output of the same size units, and thus economizing on the general cost of plant operation. Here is one of the ever recurring instances in chemical manufacturing where it becomes more advantageous to sacrifice apparent theoretical efficiency in favor of industrial expediency.

All this does not diminish the fact that the larger electrochemical industries can only thrive where cheap power is available.

Importance of cheap power for electrochemical processes

Modern progress of electrical engineering has given us the means to utilize so-called natural powers; until now, however, we have only availed ourselves of the water-power developed from rivers, lakes, and waterfalls. As far as larger electric power generation is concerned, the use of the wind, or the tide, or the heat of the sun, represents, up till now, nothing much beyond a mere hope of future possibilities.

In the meantime, it so happens, unfortunately, that many of the most abundant water-powers of the world are situated in places of difficult access, far removed from the zone of possible utilization.

Cost of water-power in the United States still too high

But, precisely on this account, it would appear, at first sight, as if the United States, with some of her big water-powers situated nearer to active centers of consumption, would be in an exceptionally favorable condition for the development of electrochemical industries. On closer examination, we find, however, that the cost of water-power, as sold to manufacturers, is, in general, much higher than might be expected; at any rate, it is considerably more expensive than the cost of electric power utilized in the Norway nitrate enterprises.

This is principally due to the fact that in the United States, water-power, before it is utilized by the electrolytic manufacturer, has already to pay one, two, and sometimes three, profits, to as many intermediate interests, which act as so many middlemen between the original water-power and the consumer. Only in such instances as in Norway, where the electrochemical enterprise and the development of the water-power are practically in the same hands, can electric current be calculated at its real cheapest cost.

Neither should the fact be overlooked that the best of our water-powers in the East are situated rather far inland. Although this does not matter much for the home market, it puts us at a decided disadvantage for the exportation of manufactured goods, in comparison again with Norway, where the electrolytic plants are situated quite close to a good sea-harbor open in all seasons.

Increasing use of waste gas and producer gas

Some electrochemical enterprises require cheap fuel just as much as cheap power; and, on this account, it has proved sometimes more advantageous to dispense entirely with water-power by generating gas for fuel as well as for power from cheap coal or still cheaper peat.

At present, most of our ways of using coal are still cumbersome and wasteful, although several efficient methods have been developed which some day will probably be used almost exclusively, principally in such places where lower grades of cheap coal are obtainable.

Mond-gas

I refer here particularly to the valuable pioneer work of that great industrial chemist, Mond, on cheap water-gas production, by the use of a limited amount of air in conjunction with water vapor.

More recently, this process has been extended by Caro, Frank and others, to the direct conversion of undried peat into fuel-gas.

By the use of these processes, peat or lower grades of coal, totally unsuitable for other purposes, containing, in some instances, as much as 60 to 70% of incombustible constituents, can be used to good advantage in the production of fuel for power generation.

Whether Mond-gas will ever be found advantageous for distribution to long distances is questionable, because its heating value per cubic foot is rather less than that of ordinary water-gas, but this does not interfere with its efficient use in internal combustion engines.

In general, our methods for producing or utilizing gas in our cities do scant justice to the extended opportunities indicated by our newer knowledge.

Antiquated municipal specifications for gas testing

Good fuel-gas could be manufactured and distributed to the individual household consumer at considerably cheaper rates, if it were not for antiquated municipal specifications, which keep on prescribing photometric tests instead of insisting on standards of fuel value, which makes the cost of production unnecessarily high, and disregards the fact that, for lighting, the Welsbach mantle has rendered obsolete the use of highly carbureted gas as a bare flame. But for those unfortunate specifications, cheap fuel-gas might be produced at some advantageous central point, where very cheap coal is available; such heating gas could be distributed to every house and every factory, where it could be used cleanly and advantageously, like natural gas, doing away at once with the black coal smoke nuisance, which now practically compels a city like New York to use nothing but the more expensive grades of anthracite coal. It would eliminate, at the same time, all the bother and expense caused through the clumsy and expensive methods of transportation and handling of coal and ashes; it would relieve us from many unnecessary middlemen which now exist between coal and its final consumer.

Great economic possibilities of cheap fuel-gas

New power centers to compete with water-power

The newer large-sized internal combustion engines are introducing increasing opportunities for new centers of power production where waste gas of blast-furnaces or coke-ovens, or where deposits of inferior coal or peat, are available.

If such centers are situated near tidewater, this may render them still more advantageous for some electrochemical industries, which, until now, were compelled to locate near some inland water-powers.

Nor should we overlook the fact that the newer methods for the production of cheap fuel-gas offer excellent opportunities for an increased production of valuable tar by-products, and more particularly of ammonium salts; the latter would help to a not inconsiderable extent in furnishing more nitrogen fertilizer.

Increased production of ammonia and other by-products from gas

It is somewhat remarkable that a greater effort has already been made to start the industrial synthesis of nitrogen products than to economize all these hitherto wasted sources of ammonia.

Our unbalanced methods of agriculture

In fact, science indicates still other ways, somewhat of a more radical nature, for correcting the nitrogen deficiencies in relation to our food supply.

Indeed, if we will look at this matter from a much broader standpoint, we may find that, after all, the shortage of nitrogen in the world is attributable, to a large extent, to our rather one-sided system of agriculture. We do not sufficiently take advantage of the fact that certain plants, for instance those of the group of Leguminosæ, have the valuable property of easily assimilating nitrogen from the air, without the necessity of nitrogen fertilizers. In this way, the culture of certain Leguminosæ can insure enough nitrogen for the soil, so that, in rotation with nitrogen consuming crops, like wheat, we could dispense with the necessity of supplying any artificial nitrogen fertilizers.

Disturbing influence of raising too many cattle

The present nitrogen deficiency is influenced further by two other causes:

The first cause is our unnecessarily exaggerated meat diet, in which we try to find our proteid requirements, and which compels us to raise so many cattle, while the amount of land which feeds one head of cattle could furnish, if properly cultivated, abundant vegetable food for a family of five.

The second cause is our insufficient knowledge of the way to grow and prepare for human food just those vegetables which are richest in proteids. Unfortunately, it so happens that exactly such plants as, for instance, the soy-bean are not by any means easily rendered palatable and digestible; while any savage can eat raw meat, or can readily cook, boil or roast it for consumption.

The soy-bean

On this subject, we can learn much from some Eastern people, like the Japanese, who have become experts in the art of preparing a variety of agreeable food products from that refractory soy-bean, which contains such an astonishingly large amount of nutritious proteids, and which, long ago, became for Japan a wholesome, staple article of diet.

But, on this subject, the Western races have not yet progressed much beyond the point of preparing cattle-feed and paint oil from the soy-bean, although the more extended culture of this, or similar plants, might work about a revolution in our agricultural economics.

Agriculture a branch of industrial chemistry

Agriculture, after all, is nothing but a very important branch of industrial chemistry, although most people seem to ignore the fact that the whole prosperity of agriculture is based on the success of that photochemical reaction which, under the influence of the light of the sun, causes the carbon dioxide of the air to be assimilated by the chlorophyl of the plant.

Possibilities of photochemistry

It is not impossible that photochemistry, which hitherto has busied itself, almost exclusively, within the narrow limits of the art of making photographic images, will, some day, attain a development of usefulness at least as important as all other branches of physical chemistry. In this broader sense, photochemistry seems an inviting subject for the agricultural chemist. The possible rewards in store in this almost

virgin field may, in their turn, by that effect of superinduction between industry and science, bring about a rapid development similar to what we have witnessed in the advancement of electricity, as well as chemistry, which both began to progress by bounds and leaps, way ahead of other sciences, as soon as their growing industrial applications put a high premium on further research.

Photochemistry may allow us some day to obtain chemical effects hitherto undreamed of. In general, the action of light in chemical reactions seems incomparably less brutal than all means used heretofore in chemistry. This is the probable secret of the subtle chemical syntheses which happen in plant life. To try to duplicate these delicate reactions of nature by our present methods of high temperatures, electrolysis, strong chemicals and other similar torture-processes, seems like trying to imitate a masterpiece of Gounod by exploding a dynamite cartridge between the strings of a piano.

Some problems for the future

But there are endless other directions for scientific research, relating to industrial applications, which, until now, do not seem to have received sufficient attention.

For instance, from a chemical standpoint, the richest chemical enterprise of the United States, the petroleum industry, has hitherto chiefly busied itself with a rather primitive treatment of this valuable raw material, and little or no attention has been paid to any methods for transforming at least a part of these hydrocarbons into more ennobled products of commerce than mere fuel or illuminants.

Rudimentary chemical development of the petroleum industry

Synthetic rubber

A hint as to the enormous possibilities which may be in store in that direction, is suggested by the recent work in Germany and England on synthetic rubber; the only factor which prevents extending the laboratory synthesis of rubber into an immense

industrial undertaking, is that we have not yet learned how to make cheaply the isoprene or other similar non-saturated hydrocarbons which are the starting point in the process which changes their molecules, by polymerization, into rubber.

Cellulose and starch

Nor has our science begun to find the best uses for such inexpensive and never exhaustible vegetable products as cellulose or starch. Quite true, several important manufactures, like that of paper, nitrocellulose, glucose, alcohol, vinegar and some others, have been built on it; but to the chemist at least, it seems as if a much greater development is possible in the cheaper and more extended production of artificial fiber. Although we have succeeded in making so-called artificial silk, this article is still very expensive; furthermore, we have not yet produced a cheap, good, artificial fiber of the quality of wool.

Artificial production of soluble potash-salts

If we have made ourselves independent of Chile for our nitrogen supply, we are still absolutely at the mercy of the Stassfurt mines in Germany for our requirements of soluble potash-salts, which are just as necessary for agriculture. Shall we succeed in utilizing some of the proposed methods for converting that abundant supply of feldspar, or other insoluble potash-bearing rocks, into soluble potash-salts by combining the expensive heat treatment with the production of another material like cement, which would render the cost of fuel less exorbitant? Or shall the problem be solved in setting free soluble potassium salts as a by-product in a reaction engendering other staple products consumed in large quantities?

Our ignorance relative to constitution of the globe

We have several astonishingly conflicting theories about the constitution of the center of the globe, but we have not yet developed the means to penetrate the world's crust beyond some deep mines—merely an imperceptible faint scratch on

the surface—and in the meantime, we keep on guessing, while to-day astronomers know already more about the surface of the planet Mars than we know about the interior of the globe on which we live.

Intense pressures and heat

Nor have we learned to develop or utilize the tremendous pressures under which most minerals have been formed, and still less do we possess the means to try these pressures, in conjunction with intensely high temperatures.

No end of work is in store for the research chemist, as well as for the chemical engineer, who can think by himself, without always following the beaten track. We are only at the beginning of our successes, and yet, when we stop to look back to see what has been accomplished during the last generations, that big jump from the rule-of-thumb to applied science is nothing short of marvelous.

A retrospect

Conservation of energy ignored seventy years ago

Whoever is acquainted with the condition of human thought to-day must find it strange, after all, that scarcely seventy years ago, Mayer met with derision even amongst the scientists of the time, when he announced to the world that simple but fundamental principle of the conservation of energy.

Pasteur's ideas on fermentation ridiculed by Liebig

We can hardly conceive that just about the time the Columbia School of Mines was founded, Liebig was still ridiculing Pasteur's ideas on the intervention of micro-organisms in fermentation, which have proved so fecund in the most epoch-making applications in science, medicine, surgery and sanitation, as well as in many industries.

Science admits no "authorities"

Fortunately, true science, contrary to other human avocations, recognizes nobody as an "authority," and is willing to change her beliefs as often as better studied facts warrant it; this

difference has been the most vital cause of her never ceasing progress.

To the younger generation, surrounded with research laboratories everywhere, it may cause astonishment to learn that scarcely fifty years ago, that great benefactor of humanity, Pasteur, was still repeating his pathetic pleadings with the French government to give him more suitable quarters than a damp, poorly lighted basement, in which he was compelled to carry on his research; and this was, then, the condition of affairs of no less a place than Paris, the same Paris that was spending, just at that time, endless millions for the building of her new Opera-Palace.

Pasteur's rudimentary laboratory facilities

Such facts should not be overlooked by those who might think that America has been too slow in fostering chemical research.

Reason for America's slow development of chemical industry

If the United States has not participated as early as some European countries in the development of industrial chemistry, this was chiefly because conditions here were so totally different from those of nations like Germany, England and France, that they did not warrant any such premature efforts.

In a country as full of primary resources, agriculture, forests, mines and the more elementary industries directly connected therewith, as well as the problems of transportation, appealed more urgently to American intellectual men of enterprise.

Why should anybody here have tried to introduce new difficult or risky chemical industries, when on every side more urgently important fields of enterprise were inviting all men of initiative?

Chemical industries develop along the lines furnished by the most immediate needs of a country. Our sulphuric acid industry, which can boast to-day of a yearly production of about three million tons, had to begin in an exceedingly

humble way, and the first small amounts of sulphuric acid manufactured here found a very scant outlet.

It required the growth of such fields of application as petroleum refining, superphosphates, explosives and others, before the sulphuric acid industry could grow to what it is to-day.

Exports and imports between the United States and Germany

At present, similar influences are still dominating our chemical industries; they are generally directed to the mass production of partly manufactured articles. This allows us to export, at present, to Germany, chemicals in crude form, but in greater value than the total sum of all the chemical products we are importing from her; although it can not be denied that a considerable part of our imports are products like alizarine, indigo, aniline dyes and similar synthetic products which require higher chemical manufacturing skill.

In this connection, it may be pointed out that our exports of oleomargarine, to Germany alone, are about equivalent to our imports of aniline dyes.

Some chemical industries in which the United States was pioneer

But all this does not alter the fact that in several important chemical industries the United States has been a pioneer. Such flourishing enterprises as that of the artificial abrasives, carborundum and alundum, calcium carbide, aluminum and many others, testify how soon we have learned to avail ourselves of some of our water-power.

One of the most important chemical industries of the world, the sulphite cellulose industry, of which the total annual production amounts to three and a half million tons, was originated and developed by a chemist in Philadelphia, B. C. Tilgman. But its further development was stopped for awhile on account of the same old trouble, lack of funds, after $40,000 were spent, until some years later, it was taken up again in Europe and reintroduced in the United

States, where it has developed to an annual production of over a million tons.

What has been accomplished in America in chemical enterprises, and what is going on now in industrial research, has been brilliantly set forth by Mr. Arthur D. Little.[1]

Early beginning of study of chemistry in the United States

Nor at any time in the history of the United States was chemistry neglected in this country; this has recently been brought to light in the most convincing manner by Professor Edgar F. Smith of Philadelphia.[2]

The altruistic fervor of that little group of earlier American chemists, who, in 1792, founded the Chemical Society of Philadelphia (probably the very first chemical society in the world), and in 1811, the Columbia Chemical Society of Philadelphia, is best illustrated by an extract of one of the addresses read at their meeting in 1798:

"The only true basis on which the independence of our country can rest are agriculture and manufactures. To the promotion of these nothing tends in a higher degree than chemistry. It is this science which teaches man how to correct the bad qualities of the land he cultivates by a proper application of the various species of manure, and it is by means of a knowledge of this science that he is enabled to pursue the metals through the various forms they put on in the earth, separate them from substances which render them useless, and at length manufacture them into the various forms for use and ornament in which we see them. If such are the effects of chemistry, how much should the wish for its promotion be excited in the breast of every American! It is to a general diffusion of knowledge of this science, next to the virtue of our countrymen, that we are to look for the firm establishment of our independ-

[1] Journal of Industrial and Engineering Chemistry. Vol. 5, No. 10. October, 1913.

[2] "Chemistry in America." Published by D. Appleton & Co. New York and London, 1914.

ence. And may your endeavors, gentlemen, in this cause, entitle you to the gratitude of your fellow-citizens."

This early scientific spirit has been kept alive throughout the following century by such American chemists as Robert Hare, E. N. Horsford, Wolcott Gibbs, Sterry Hunt, Lawrence Smith, Carey Lea, Josiah P. Cooke, John W. Draper, Willard Gibbs and many others still living.

Present conditions of chemistry in America

Present conditions in America can be measured by the fact that the American Chemical Society alone has over seven thousand members, and the Chemists' Club of New York has more than a thousand members, without counting the more specialized chemical organizations, equally active, like the American Institute of Chemical Engineers, the American Electrochemical Society and many others.

During the later years, chemical research is going on with increasing vigor, more specially in relation to chemical problems presented by enterprises which at first sight seem rather remote from the so-called chemical industry.

Research in America

But the most striking symptom of newer times is that some wealthy men of America are rivaling each other in the endowment of scientific research on a scale never undertaken before, and that the scientific departments of our Government are enlarging their scope of usefulness at a rapid rate.

But we are merely at the threshold of that new era where we shall learn better to use exact knowledge and efficiency to bring greater happiness and broader opportunities to all.

However imposing may appear the institutions founded by the Nobels, the Solvays, the Monds, the Carnegies, the Rockefellers and others, each of them is only a puny effort to what is bound to come when governments will do their full share. Fancy that if, for instance, the Rockefeller Institute is spending to good advantage about

Insufficiency of our present efforts compared to what ought to be done

half a million dollars per annum for medical research, the chewing-gum bill of the United States alone would easily support half a dozen Rockefeller Institutes; and what a mere insignificant little trickle all these research funds amount to, if we have the courage to compare them to that powerful gushing stream of money which yearly drains the war budget of all nations.

In the meantime, the man of science is patient and continues his work steadily, if somewhat slowly, with the means hitherto at his disposal. His patience is inspired by the thought that he is not working for to-day, but for to-morrow. He is well aware that he is still surrounded by too many "men of yesterday," who delay the results of his work.

Efficiency *vs.* waste

Sometimes, however, he may feel discouraged that the very efficiency he has succeeded in reaching at the cost of so many painstaking efforts, in the economical production of such an article of endlessly possible uses, as Portland Cement, is hopelessly lost many times over and over again, by the inefficiency, waste and graft of middlemen and political contractors, by the time it gets on our public roads, or in our public buildings. Sometimes the chaos of ignorant brutal waste which surrounds him everywhere may try his patience. Then again, he has a vision that he is planting a tree which will blossom for his children and will bear fruit for his grandchildren.

The man of science provides for future generations

In the meantime, industrial chemistry, like all other applications of science, has gradually called into the world an increasing number of men of newer tendencies, men who bear in mind the future rather than the past, who have acquired the habit of thinking by well-established facts, instead of by words, of

New type of men evolved by scientific education

aiming at efficiency instead of striking haphazard at ill-defined purposes. Our various engineering schools, our universities, are turning them out in ever increasing numbers, and better and better prepared for their work. Their very training has fitted them out to become the most broad-minded progressive citizens.

Private gain or public service

However, their sphere of action, until now, seldom goes beyond that of private technical enterprises for private gain. And yet, there is not a chemist, not an engineer, worthy of the name, who would not prefer efficient, honorable public service, freed from party politics, to a mere money-making job.

Government by engineers or by lawyer-politicians?

But most governments of the world have been run for so long almost exclusively by lawyer-politicians, that we have come to consider this as an unavoidable evil, until sometimes a large experiment of government by engineers, like the Panama Canal, opens our eyes to the fact that, after all, successful government is—first and last—a matter of efficiency, according to the principles of applied science.

Benjamin Thompson (Count Rumford). Bavaria governed by a chemist

Was it not one of our very earliest American chemists, Benjamin Thompson, of Massachusetts, later knighted in Europe as Count Rumford, who put in shape the rather entangled administration of Bavaria by introducing scientific methods of government?

Pasteur was right when one day, exasperated by the politicians who were running his beloved France to ruin, he exclaimed:

Applied science and the destiny of nations

"In our century, science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly, the tiring daily discussions of politics seem to be our guide. Empty appearances!—What really leads us forward are a few scientific discoveries and their applications."